Chapter 5
Results and Discussion

Effectiveness of Paint Removal

XRF Measurements Before and After Paint Removal

Tables 6 and 7 present descriptive statistics for the XRF measurements obtained before and after paint removal on wood and brick substrates, respectively, for each technology combination. The descriptive statistics include the number of samples, arithmetic mean and standard deviation, and the minimum and maximum lead concentrations. Appendix B presents the individual XRF measurements on wood and brick substrates before paint removal. Appendix C presents the individual XRF measurements on wood and brick substrates after paint removal.

Table 6. Descriptive Statistics for XRF Measurements (K & L Shell Combined) Collected Before and After Paint Removal on Exterior Wood Siding

Technology Combination	Lead Concentration (mg/cm^2)				
	N	Mean	Std. Dev.	Minimum	Maximum
Before Paint Removal					
Torbo® with Blastox®	15	36.9	9.52	15.5	51.9
Torbo® with PreTox 2000	15	29.7	9.66	13.1	41.4
After Paint Removal					
Torbo® with Blastox®	75	0.24	0.22	0	1.1
Torbo® with PreTox 2000	75	0.16	0.16	0	0.70

A one-tailed t-test was used to determine whether the mean lead concentration after paint removal was significantly less than 1 mg/cm^2 both by substrate (i.e., wood and brick) and overall for each technology combination. In every case, both by substrate and overall, the results show that both Torbo®-Blastox® and Torbo®-PreTox 2000 reduced lead concentrations on wood and brick to a level significantly below 1 mg/cm^2. Table 8 presents the results of the t-test comparisons.

Table 7. Descriptive Statistics for XRF Measurements (K & L Shell Combined) Collected Before and After Paint Removal on Exterior Brick

Technology Combination	Lead Concentration (mg/cm^2)				
	N	Mean	Std. Dev.	Minimum	Maximum
Before Paint Removal					
Torbo® with Blastox®	15	5.59	1.78	1.5	9.7
Torbo® with PreTox 2000	15	8.18	3.71	3.9	15.2
After Paint Removal					
Torbo® with Blastox®	75	0.14	0.09	0	0.4
Torbo® with PreTox 2000	75	0.11	0.14	0	1.1

Table 8. Effectiveness of Paint Removal from Exterior Wood Siding and Brick

Technology Combination	Substrate	Site	N	Mean (mg/cm^2)	t statistic	p-value
Torbo® with Blastox®	Wood	1	25	0.10	-40.2	<0.0001
		2	25	0.37	-16.9	<0.0001
		5	25	0.24	-14.9	<0.0001
		Overall	75	0.24	-30.0	<0.0001
	Brick	2	25	0.12	-57.6	<0.0001
		4	25	0.17	-44.0	<0.0001
		6	25	0.12	-52.7	<0.0001
		Overall	75	0.14	-86.2	<0.0001
Torbo® with PreTox 2000	Wood	3	25	0.13	-26.9	<0.0001
		4	25	0.18	-23.7	<0.0001
		6	26	0.15	-29.8	<0.0001
		Overall	76	0.16	-46.2	<0.0001
	Brick	1	25	0.07	-55.1	<0.0001
		3	25	0.09	-64.6	<0.0001
		5	25	0.16	-19.4	<0.0001
		Overall	75	0.11	-54.0	<0.0001

The one-tailed t-test requires a distributional assumption that the data be normally distributed. Although the XRF data (Appendix C) were not reasonably described by a normal distribution, the results of the t-tests were so highly significant (<<0.0001) that a violation of this distributional assumption is not consequential. However, these data were also analyzed using a non-parametric Sign Rank Test which does not require that the data follow a normal distribution (i.e., a distribution-free method). The results of the Signed Rank Tests were also highly significant and agreed with the respective parametric t-test in every case.

Comparison of XRF Measurements and ICP-AES Analysis

Tables 9 and 10 present descriptive statistics for the XRF measurements obtained before and after paint removal on wood and brick substrates, respectively, for each technology combination. The descriptive statistics include the number of samples, arithmetic mean and standard deviation, and minimum and maximum lead concentrations. Appendix D presents the individual ICP-AES sample analyses on wood and brick substrates before paint removal. Appendix E presents the individual ICP-AES sample analyses on wood and brick substrates after paint removal. The individual sample concentrations are presented as both mg/cm^2 and µg/g.

The Wilcoxon Rank Sum Test was used to compare lead concentrations measured by XRF and ICP-AES on the wood and brick substrates both before and after paint removal. The Wilcoxon test does not require the distributional assumption of normality. The lead concentrations determined by ICP-AES and XRF measurements before paint removal on wood were not significantly different (p=0.1055); however, the measurements before paint removal on brick were significantly different (p=0.0001). The lead concentrations determined by ICP-AES and XRF measurements after paint removal on wood were significantly different (p=0.0331); however, the measurements after paint removal on brick were not significantly different (p=0.5504).

Table 9. Lead Concentrations in Paint and on Wood Measured by ICP-AES and XRF (K & L Shell Combined)

Method of Measurement	Lead Concentration (mg/cm^2)				
	N	Mean	Std. Dev.	Minimum	Maximum
Before Paint Removal					
ICP-AES	18	28.2	12.8	9.1	51.6
XRF (L & K Shell)	30	33.3	10.1	13.1	51.9
After Paint Removal					
ICP-AES	30	0.37	0.50	0.01	2.68
XRF (L & K Shell)	150	0.20	0.20	0	1.10

Table 10. Lead Concentrations in Paint and on Brick Measured by ICP-AES and XRF (K & L Shell Combined)

Method of Measurement	Lead Concentration (mg/cm^2)				
	N	Mean	Std. Dev.	Minimum	Maximum
Before Paint Removal					
ICP-AES	18	2.93	2.11	0.20	9.1
XRF (L & K Shell)	30	6.89	3.15	1.5	15.2
After Paint Removal					
ICP-AES	30	0.20	0.30	0.005	1.39
XRF (L & K Shell)	150	0.13	0.12	0	1.10

Condition of Abated Surface

The physical appearance of the abated wood and brick substrates was assessed by visual examination to determine the extent of damage and degree of repair required prior to painting of the surface. The wood surfaces were examined to determine whether the woodgrain was lifted or feathered, the edges of the boards were rounded, or the surface was pitted or grooved, as well as the general evenness of the surface. The brick surfaces were examined to determine whether the surface was spalled and the extent that the mortar in the joints was dislodged.

Wood Surfaces

Overall, there did not appear to be a noticeable difference in the appearance of the abated wood substrate between the two technology combinations. Both technology combinations effectively removed the paint coating to bare substrate with minimal damage to the underlying substrate. Overall, <10 percent of the surfaces were slightly grooved or pitted; none of the surfaces displayed lifted or feathered woodgrain. Thus, the resultant substrate would require light sanding prior to painting. An evaluation was not conducted to measure the potential exposures to airborne lead during this activity. Hence, users of this technology should be cautioned that sanding of the abated substrate could result in elevated exposures to lead particulate. In the absence of actual exposure monitoring data, appropriate respiratory protection and personal protective clothing should be worn.

It should be noted that the initial wet abrasive blasting of the wood siding at Site 1 resulted in rounding of the edges of the boards. This apparently was due to the sharpness of the coal slag particles. Hence, mineral sand or other abrasive media would have been a more appropriate material.

Brick Surfaces

Overall, there did not appear to be a noticeable difference in the appearance of the abated brick substrate between the two technology combinations. Both technology combinations effectively removed the paint coating to bare substrate with no apparent damage to the underlying substrate (i.e., the surface was not spalled). Overall, approximately 25 percent of the mortar joints may require tuck pointing. A mineral sand abrasive was used for these demonstrations.

Paint Removal Rates

Table 11 presents the paint removal rates for wood and brick substrates for both technology combinations. The removal rates represent the average of the three replicate demonstrations per technology combination per substrate. The higher removal rates from brick may be attributed to the removal from a single expanse of wall versus the multiple wood wall surfaces, as well as the time required to exercise more care not to damage the softer wood substrate.

Table 11. Average Paint Removal Rates from Wood and Brick Substrates

Technology Combination	Substrate	Paint Removal (ft^2)	Removal Time (Hours)	Removal Rate (ft^2/hr)
Torbo® with Blastox®	Wood	354.3	4.26	83.2
Torbo® with PreTox 2000		370.1	5.23	70.8
Overall		362.2	4.74	76.4
Torbo® with Blastox®	Brick	646.3	5.45	118.6
Torbo® with PreTox 2000		609.3	5.02	121.4
Overall		627.8	5.24	119.8

Characterization of Abrasive Media Paint Debris

Coal Slag Paint Debris from Wood Substrate

Table 12 presents descriptive statistics for the TCLP analysis of coal slag paint debris from wet abrasive blasting of the wood siding. The descriptive statistics include the number of samples, arithmetic mean and standard deviation, and the minimum and maximum lead concentrations. Appendix F presents the individual TCLP sample results.

The 80 percent confidence interval was used to determine whether the mean leachable lead level in the coal slag paint debris was significantly greater than the RCRA regulatory threshold of 5 mg/L. If the upper limit of the 80 percent confidence interval for the mean is $\geq$ 5 mg/L, the material is considered to be a RCRA hazardous waste. Table 13 presents the mean leachable lead levels and corresponding upper confidence limits for the abrasive paint debris by site and overall for both technology combinations. Overall, the abrasive paint debris from both technology combinations was determined to be a hazardous waste. If examined on a site-by-site basis, the debris is also determined to be a hazardous waste. Another field demonstration of the Torbo®-Blastox® technology combination showed similar lead stabilization results.[16]

The mean leachable lead levels in abrasive media debris generated from the removal of paint from wood by the two technology combinations were compared by using a standard two-sample t-test. The mean leachable lead level in the debris generated from the Torbo®-Blastox® combination (21.3 mg/L) was not significantly different (p=0.4459) from the mean leachable lead level in the debris generated from the Torbo®-PreTox 2000 combination (14.8 mg/L).

Table 12. Descriptive Statistics for Leachable Lead (TCLP) Measured in Coal Slag Paint Debris from Wood Substrates

Technology Combination	Leachable Lead Concentration (mg/L)				
	N	Mean	Std. Dev.	Minimum	Maximum
Torbo®-Blastox®	6	21.3	17.6	3.7	52.0
Torbo®-PreTox 2000	9	14.8	14.1	0.3	37.0

Table 13. Characterization of Coal Slag Paint Debris from Wood Substrates

Technology Combination	Substrate	Site	N	Leachable Lead Level	
				Mean (mg/L)	80% UCL for Mean
Torbo®-Blastox®	Wood	1	2	12.4	39.0
		2	2	15.5	47.9
		5	2	36.0	85.2
		Overall	6	21.3	31.9
Torbo®-PreTox 2000	Wood	3	3	7.7	20.2
		4	3	29.7	39.2
		6	3	7.1	17.5
		Overall	9	14.8	21.4

The debris was re-sampled due to a concern that the initial sampling data (Table 13) may not have been representative of the true concentration of leachable lead in the coal slag paint debris. The sampling strategy was consistent with the ASTM Quartering Method.[17] Table 14 presents the mean leachable lead levels and corresponding upper confidence limits for the abrasive paint debris for both technology combinations. Appendix F presents the individual TCLP sample results. The mean leachable lead levels from the initial sampling (Table 13) were compared to those from the re-sampling (Table 14) using a standard two-sample t-test. The initial mean leachable lead level in the debris generated from the Torbo®-Blastox® combination (21.3 mg/L) was not significantly different (p=0.2721) from the mean leachable lead level in the re-sampled debris (12.5 mg/L). Similarly, the initial mean leachable lead level in the debris generated from the Torbo®-PreTox 2000 combination (14.8 mg/L) was not significantly different (p=0.7742) from the mean leachable lead level in the re-sampled debris (13.0 mg/L). Hence, these data confirm that the mean leachable lead level determined by the initial sampling strategy was representative.

Table 14. Leachable Lead Levels in Re-sampled Debris from Abrasive Blasting of Wood Substrates

Technology Combination	N	Mean (mg/L)	80% UCL for Mean
Torbo®-Blastox®	8	12.5	18.0
Torbo®-PreTox 2000	8	13.0	19.0

In addition to the re-sampling of the abrasive media paint debris, the leachable lead content was also determined for the debris that had been treated with additional amounts of Blastox® or PreTox 2000 to achieve the blend ratio or simulate the mil application thickness, respectively, based on the paint film thickness (average 71 mil). Table 15 presents the mean leachable lead levels and corresponding upper confidence limits for the treated debris. Appendix F presents the individual TCLP sample results. The abrasive media paint debris treated with additional amounts of PreTox 2000 were determined to be a non-hazardous waste (i.e., the 80% UCL (mg/L) was <5 mg/L). The abrasive media paint debris treated with additional amounts of Blastox®, however, remained as a hazardous waste (i.e., the 80% UCL (mg/L) was >5 mg/L).

Table 15. Leachable Lead Levels in Abrasive Media Paint Debris from Wood Substrates Treated with Additional Blastox® or PreTox 2000

Technology Combination	N	Mean (mg/L)	80% UCL for Mean
Torbo®-Blastox®	2	21.1	41.9
Torbo®-PreTox 2000	2	0.1	NA[a]

[a] Not applicable. The individual values were all 0.1 mg/L.

Mineral Sand Paint Debris from Brick Substrate

Table 16 presents descriptive statistics for the TCLP analysis of mineral sand paint debris from wet abrasive blasting of the brick wall. The descriptive statistics include the number of samples, arithmetic mean and standard deviation, and the minimum and maximum lead concentrations. Appendix G presents the individual TCLP sample results.

Table 16. Descriptive Statistics for Leachable Lead (TCLP) Measured in Mineral Sand Paint Debris from Brick Substrates

Technology Combination	Leachable Lead Concentration (mg/L)				
	N	Mean	Std. Dev.	Minimum	Maximum
Torbo®-Blastox®	6	7.8	2.1	3.9	10.0
Torbo® -PreTox 2000	6	8.1	9.0	0.2	20.0

Table 17 presents the mean leachable lead levels and corresponding upper confidence limits for the abrasive paint debris by site and overall for both technology combinations. Overall, the abrasive paint debris from both technology combinations was determined to be a hazardous waste. If examined on a site-by-site basis, the debris is also determined to be a hazardous waste, with one exception. The two samples collected from debris at Site 1 (Torbo®-Blastox®) showed an 80% UCL of 3.9, which by itself would not be classified as a hazardous waste.

Table 17. Characterization of Mineral Sand Paint Debris from Brick Substrates

Technology Combination	Substrate	Site	N	Leachable Lead Level	
				Mean (mg/L)	80% UCL for Mean
Torbo®-Blastox®	Brick	2	2	1.1	3.9
		4	2	19.5	21.0
		6	2	3.6	9.6
		Overall	6	8.1	13.5
Torbo®-PreTox 2000	Brick	1	2	9.4	11.4
		3	2	5.9	11.9
		5	2	8.3	9.5
		Overall	6	7.8	9.1

The mean leachable lead levels in abrasive media debris generated from the removal of paint from brick by the two technology combinations were compared by using a standard two-sample t-test. The mean leachable lead level in the debris generated from the Torbo®-Blastox® combination (8.1 mg/L) was not significantly different (p=0.9555) from the mean leachable lead level in the debris generated from the Torbo®-PreTox 2000 combination (7.8 mg/L).

Overall, the abrasive media paint debris characterization results (Tables 12-17) are somewhat surprising. The leachablility of lead is affected by many factors including, type of lead in paint, resins used in the paint, age of the paint, particle size, and others.[18-19] The manufacturers of the stabilization technologies postulate that the ineffectiveness of their respective products in this study was due to insufficient product added or applied to stabilize the concentration of lead present in the paint. The reason(s) why these stabilization technologies were ineffective under the conditions of this study is equivocal.

Blastox®--The material supplier provided a 20% and 15% blend ratio of Blastox® with the coal slag and mineral sand abrasives for use on the wood and brick substrates, respectively. A 30% and 20% blend ratio of Blastox® with the respective abrasives would have been preferred by the manufacturer. Hence, the optimum blend ratio was not used in the demonstration. Mis-communication between the manufacturer and the abrasive supplier resulted in the incorrect blending ratio of Blastox® with the abrasive. Subsequently, the manufacturer issued a technical bulletin to minimize the probability of this blending error occurring in the future.[20]

PreTox 2000--The manufacturer of PreTox 2000 recommends a 10-40 mil (wet) thickness application; a 40 mil (wet) thickness was applied to both the wood and brick substrates. A 60 mil (wet) thickness application for the wood substrates would have been preferred by the manufacturer. Hence, the optimum application mil thickness was not used in the demonstration.

Air Measurements

Personal and Area Air Measurements

Tables 18 and 19 present descriptive statistics for the airborne lead concentrations measured in the personal breathing zone samples collected on the operator and helper and in the perimeter areas (outside of the containment) during paint removal from the wood and brick substrates, respectively. The descriptive statistics include the number of samples, arithmetic mean, the minimum and maximum concentrations measured during the actual period of sampling, and the same parameters for the corresponding 8-hour time-weighted average (TWA) exposure concentrations. Appendix H presents individual air sampling results.

Table 18. Descriptive Statistics for Personal Zone and Area Air Concentrations of Lead Measured During Removal of Paint from Wood

Technology Combination	N	Lead Concentration (µg/m³)					
		Measured During Sampling Period			8-hour TWA		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
Personal Breathing Zone Samples							
Torbo®-Blastox®	3	149	37.0	230	70.9	25.1	101.5
Torbo®-PreTox 2000	3	94.3	48.0	170	55.1	34.5	86.7
Area Air Samples							
Torbo®-Blastox®	9	39.1	8.5	82.0	20.5	5.4	41.5
Torbo®-PreTox 2000	12	40.2	9.8	67.0	26.9	7.6	52.0
OSHA Permissible Exposure Limit					50		

Table 19. Descriptive Statistics for Personal Zone and Area Air Concentrations of Lead Measured During Removal of Paint from Brick

Technology Combination	N	Lead Concentration (µg/m³)					
		Measured During Sampling Period			8-hour TWA		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
Personal Breathing Zone Samples							
Torbo®-Blastox®	6	101	38.0	170	68.4	20.1	147.1
Torbo®-PreTox 2000	6	203	120	560	81.5	69.1	100.6
Area Air Samples							
Torbo®-Blastox®	18	30.0	0.76	150	21.2	0.48	144
Torbo®-PreTox 2000	16	41.3	1.4	130	24.9	0.81	79.1
OSHA Permissible Exposure Limit					50		

A standard one-tailed t-test was used to determine whether mean airborne lead levels were significantly less than the OSHA Permissible Exposure Limit of 50 µg/m³ 8-hour time-weighted average (TWA). The results of the t-tests are presented in Table 20. The mean airborne lead levels measured on area samples during paint removal from wood and brick were significantly less than the 50 µg/m³ 8-hour TWA ($p<0.001$). In all cases, the mean airbome lead levels measured by the personal breathing zone samples were significantly greater than the 50 µg/m³ 8-hour TWA.

Table 20. Comparisons of Personal and Area Air Concentrations to OSHA PEL

Technology Combination	Substrate	Type of Sample	N	Mean 8-hr TWA (µg/m³)	t statistic	p-value
Torbo® with Blastox®	Wood	Personal	3	70.9	0.8958	0.7675
		Area	9	20.5	-6.40	0.0001
	Brick	Personal	6	68.4	1.03	0.8257
		Area	18	21.2	-3.36	0.0018
Torbo® with PreTox 2000	Wood	Personal	3	55.1	0.3163	0.6091
		Area	12	26.9	-6.53	0.0001
	Brick	Personal	6	81.5	5.63	0.9975
		Area	16	24.9	-3.60	0.0013

The Wilcoxon Rank Sum Test was used to compare the average personal breathing zone concentrations of lead-containing particulate measured during paint removal from the brick (74.6 µg/m³) and wood (63.0 µg/m³) substrates. The personal breathing zone levels of lead did not vary significantly with substrate ($p=0.6396$). The same comparison was performed for the samples collected in the perimeter of the work area during paint removal from the brick (22.9 µg/m³) and wood (24.2 µg/m³) substrates. The area samples showed higher levels of lead during removal of paint from wood than from brick ($p=0.0463$).

Lead Particulate Aerodynamic Particle Size Distribution

One sample at each of Sites 1 and 2 were collected on the operator using a multistage cascade impactor during wet abrasive blasting of the brick wall. The brick was treated with a 40 mil (wet) thickness application of PreTox 2000. Appendix I presents the individual concentrations of lead measured.

Figure 1 shows the average differential lead particle size distribution for the two samples. This graph provides the particle mass concentration (C_i) in each particle-size band versus the geometric mean diameter (GMD_i), where $GMD_i = D_i \times D_{i-1}$. The lead particles generated by the wet abrasive blasting of the surface coating covers a wide-size spectrum, where the larger particles account for the greatest mass of lead.

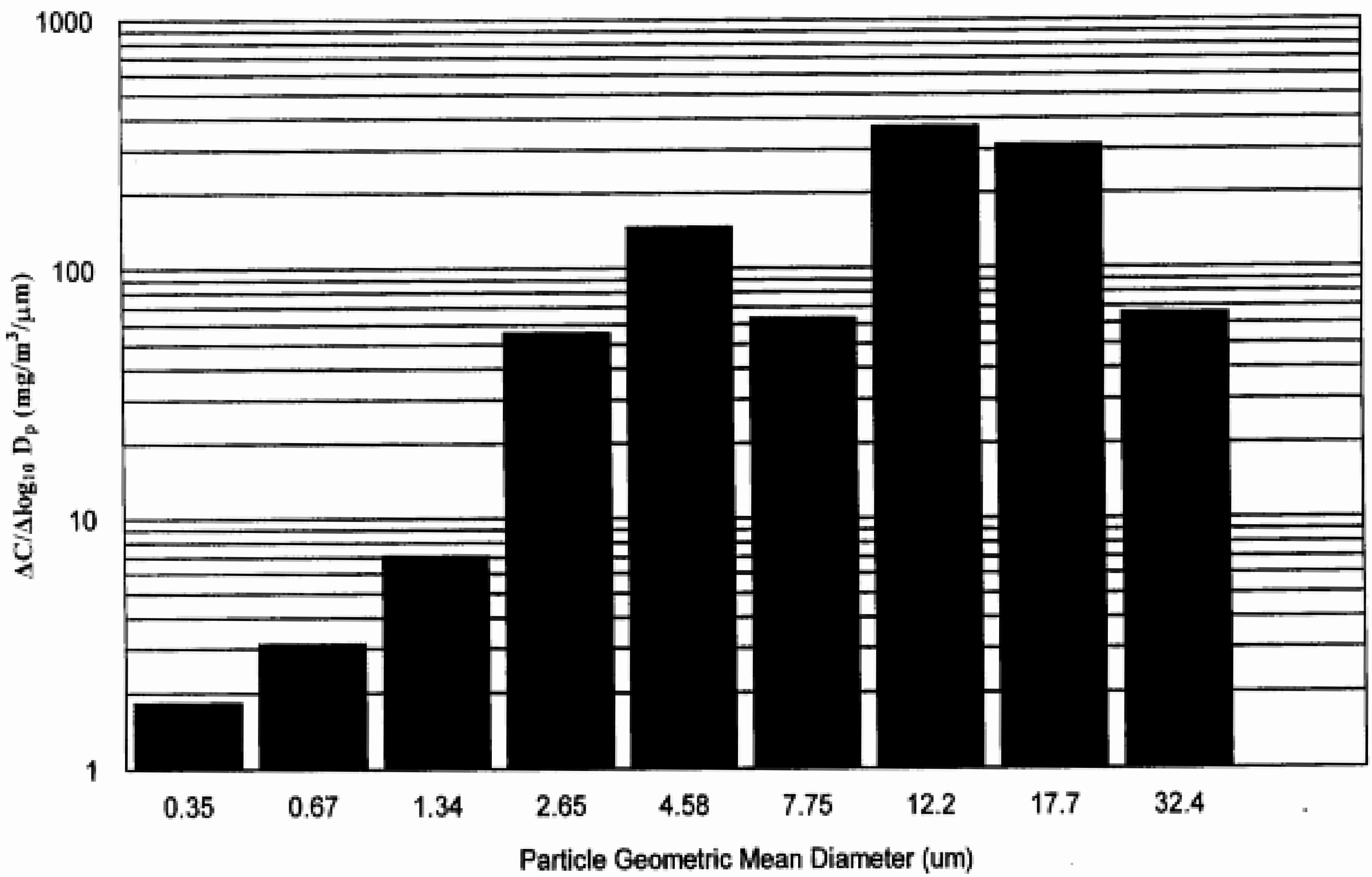

Figure 1. Differential Lead Particle Size Distribution During Wet Abrasive Blasting of Brick.

Figure 2 shows the corresponding cumulative particle size distribution for the lead particles generated during wet abrasive blasting of the surface coating. The lead particle sizes are approximately lognormally distributed; i.e., a straight line reasonably fits the data (r^2=0.9746). The mass median aerodynamic diameter (MMD) is approximately 8.3 μm. That is, 50% of the mass is represented by particles larger than the MMD and 50% of the mass is represented by particles smaller than the MMD. The geometric standard deviation (i.e., measure of the spread of the particle size distribution) was 3.4. By comparison, a geometric standard deviation of 1 represents a monodisperse aerosol (all particles are of the same size).

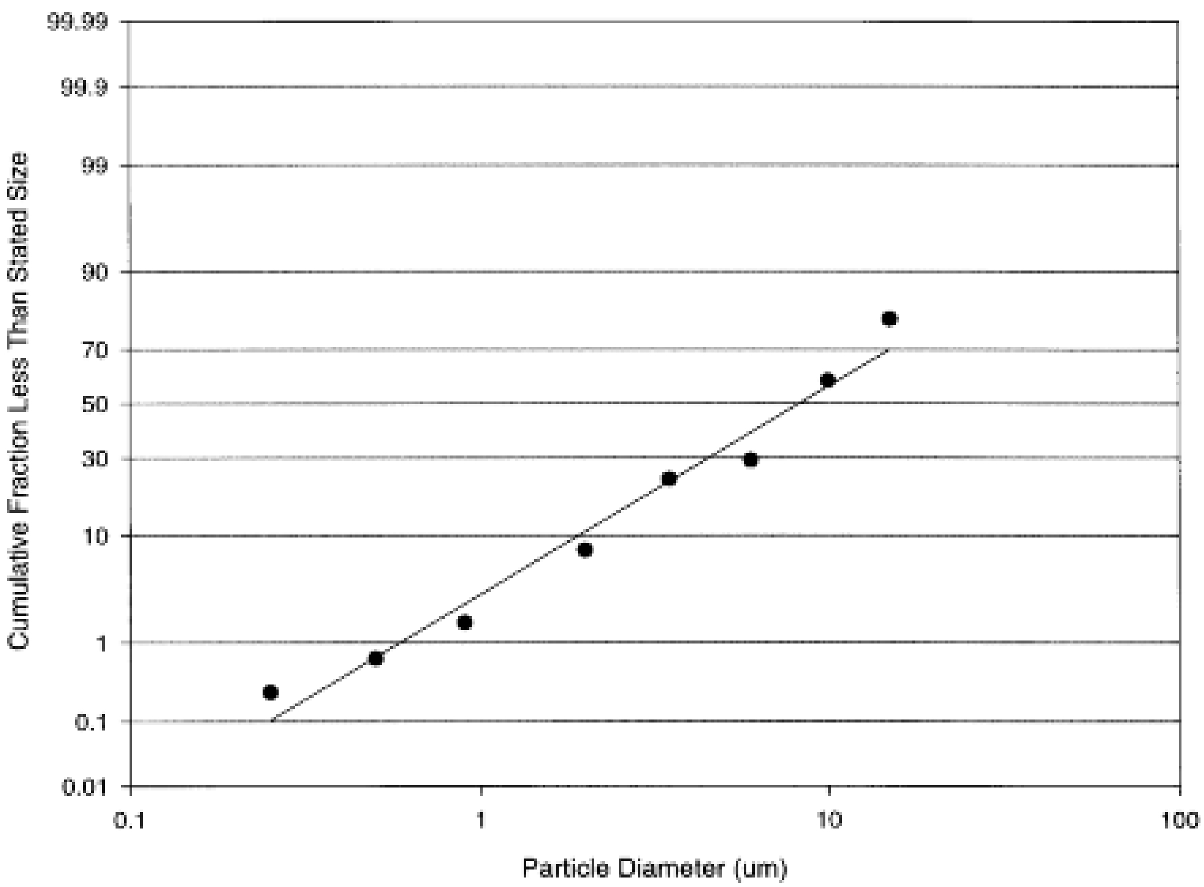

Figure 2. Lead particle size distribution cumulative probability plot.